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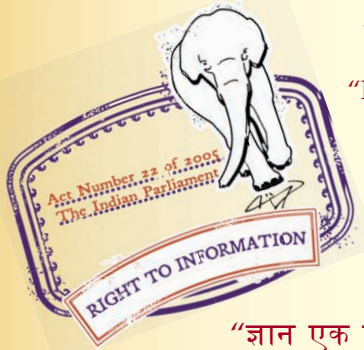
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IS 14447 (1997): Refractories for use in foundry industry -
Recommendations [MTD 15: Refractories]



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भारतीय मानक

ढ़लाई उद्योग में प्रयुक्त होने वाले अग्नि सह-संस्तुतियाँ

Indian Standard

**REFRACTORIES FOR USE IN FOUNDRY
INDUSTRY — RECOMMENDATIONS**

ICS 81.080

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Refractories Sectional Committee had been approved by the Metallurgical Engineering Division Council.

Refractories are the primary materials used in the construction of all furnaces in the ferrous and non-ferrous industries. These are used in the lining of ladles, hot metal mixers, metal retaining vessels and the flues and stacks through which hot gasses pass. Refractories are used for lining of boilers, pressure vessels, kilns and vessels using hot fluids at various temperatures. In short, refractories can be termed as those materials of construction exposed to high temperatures and corroding atmospheres and they retain their shapes and characteristics without reacting with the molten material or the corroding atmospheres.

Refractory materials are costly and a sudden failure of any refractory may result in great loss of time, product and equipment. Therefore, the selection of refractories suitable for a particular application is of paramount importance. Cost-benefit-analysis is often the basis of selection of such refractories. A refractory best suited for an application may not necessarily have the longest life. In selecting the proper refractories, a balance is struck between the initial installed cost and in-service performance.

Steel industry uses over 70 percent of the refractories consumed in the country. However, integrated steel plants employ a team of refractory engineers and specialists for selection and use of refractories. On the other hand, non-ferrous sector, the glass industry and the other high temperature and corrosion intensive industries do not always employ refractory specialists. The application of refractories in such industries is nevertheless very critical and any premature failure may lead to long down times and loss of production.

With the above problems of unorganized sector in mind, the Refractories Sectional Committee, MTD 15 decided to bring out an Handbook for Refractories which could be used as a reference book by the unorganized sector. The Refractories Sectional Committee MTD 15 allotted this work to a specially constituted Panel, MTD 15/P - 1 Panel for the Handbook for Refractories, consisting of experts from various fields of activities which the handbook will eventually cover. It is hoped that the work of this panel would lead to improvement of refractory engineering practices and overall conservation of materials and energy.

The handbook will first be published in parts as recommendations; each recommendation dealing with particular industry/process. Later on when all recommendations are published, these would be combined to form a handbook. It is intended to cover the refractories used in the following industries in the handbook for refractories:

- a) Refractories for cement kiln systems (large plants);
- b) Refractories for mini-cement plants;
- c) Refractories for petroleum and petrochemical industry;
- d) Refractories for pulp and paper industry;
- e) Refractories for lime kilns-rotary type and shaft type;
- f) Refractories used in the primary processing of non-ferrous materials such as aluminium, copper, zinc, lead, etc;
- g) Refractories used in manufacture of ferro-alloys;
- h) Refractories used in the pouring practices for ferrous and nonferrous materials;
- j) Refractories for incinerators;
- k) Refractories used by the ceramic and refractory industry;
- m) Refractories for the nuclear fuel plant;
- n) Refractories for the glass industry;

(Continued on third cover)

Indian Standard

REFRACTORIES FOR USE IN FOUNDRY INDUSTRY — RECOMMENDATIONS

1 SCOPE

This standard covers the recommendations for refractories generally used in foundry industry.

2 REFERENCES

The following Indian Standards listed below are necessary adjuncts to this standard:

<i>IS No.</i>	<i>Title</i>
6 : 1983	Moderate heat duty fireclay refractories Group 'A' (<i>fourth revision</i>)
484 : 1980	Silica refractories for general purposes (<i>second revision</i>)
3304 : 1965	Burnt chrome - magnesite refractories for general purposes
3305 : 1965	Burnt chrome - magnesite refractories for general purposes
4041 : 1987	Glossary of terms relating to refractory materials

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 4041 shall apply.

4 INTRODUCTION

In foundries, where metal is cast to shape by pouring molten metal into moulds, the main use of refractories is for lining the melting furnaces and molten metal handling systems, for example, transfer and pouring ladles, etc, and also heat treatment furnaces.

The choice of refractory for melting furnaces and allied liquid metal handling systems depends on the slag/metal chemistry, temperature conditions as well as cost. This standard outlines refractory practice for the melting furnaces commonly used in foundries, namely cupola, rotary furnaces, electric arc furnaces. Electric induction furnaces are also covered to an extent. It also touches upon the lining materials and practice for the different types of ladles in foundries.

SECTION 1

5 CUPOLA

5.1 Description

The cupola, is a vertical, cylindrical furnace, as shown in fig. 1, built of steel plates and lined with

refractory bricks or with monolithic material. The lower portion is ringed by a wind box, from which air blast enters the cupola through tuyeres to support combustion. A charging door, usually located some 6 metre above the bottom of the furnace permits loading of the cupola with fuel and the materials making up the charge. Cupolas in general use range from 0.75 to 2.25 metre in inside diameter. In charging, a bed of layer of fuel (coke) is placed at the bottom of the cupola, and charge alternating thereafter up the stack of the cupola to a predetermined height below the charging door. As combustion proceeds, the molten metal may be drawn-off directly and may flow into a force - hearth for subsequent transfer to an electric furnace or for direct casting. Cupolas are extensively used for the production of cast irons.

5.2 Refractory Practice

5.2.1 Property Requirements

The lining material should be such that it is resistant to:

- a) high temperature,
- b) abrasion,
- c) thermal shock, and
- d) chemical attack.

5.2.2 Lining Thickness

Generally the lining is about 100 mm thick. As the diameter or length of the cupola increases, the lining thickness also increases.

5.2.3 Acid Linings

5.2.3.1 Brick lining

High duty fire brick mortar for bonding the refractory lining together generally must have the following properties:

- a) It must be at least equal in refractoriness to that of the brick,
- b) It should have good workability, and
- c) It should not settle rapidly when mixed with water.

5.2.3.2 Types of mortars

Mortars can be generally classified into:

- a) hot-setting, and
- b) air-setting.

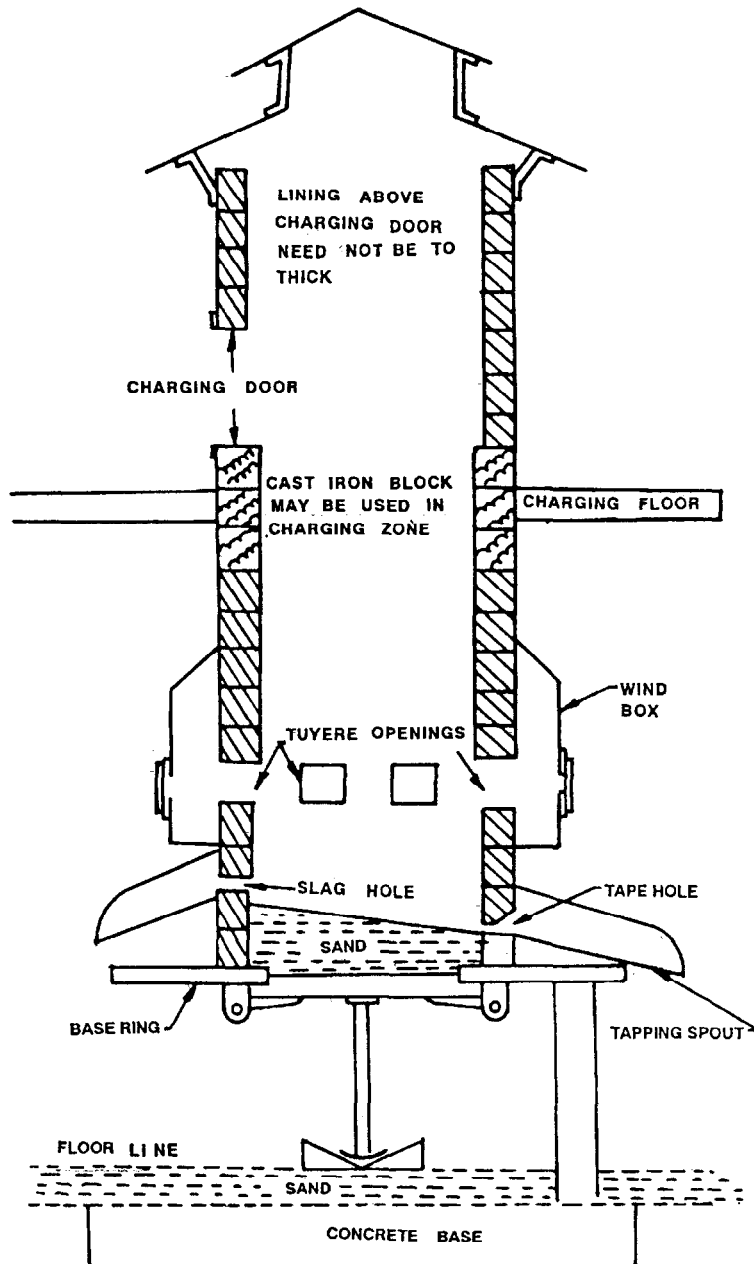


FIG. 1 CROSS SECTION OF CUPOLA SHOWING LINING

These can be further classified as wet or dry forms. These mortars are used for lining of bricks.

5.2.3.3 Monolithic linings

These are generally mixture of fireclay and silica and are applied by the gunning methods.

5.2.4 Basic Lining

The principal reason for use of basic lining is for nodular iron production. Demand for hotter iron, use of high sulphur fuel and increase in the lime-

stone charge also calls for a basic lining. It is usually made of high fired magnesite bricks or chemically bonded magnesite-chrome bricks.

5.2.4.1 Basic mortars

In cupolas with less than 225 mm lining thickness 50 or 75 mm thick high duty fireclay brick in the back of the basic lining to compensate for the higher thermal conductivity is generally used. For more than 225 mm lining thickness it is only necessary to substitute the basic lining for the heavy duty brick inner lining.

SECTION 2

6 ROTARY FURNACES

6.1 Description

This type of furnace consists of a horizontal cylindrical shell mounted on rollers and lined with refractory material. The furnace is usually tapered at both ends, the burner being at one end and an exhaust by system at the other for waste gases, often in conjunction with a recuperative system for preheating the combustion air. The fuel may be oil, gas or pulverized coal, and the air supplied by a fan or blower. The cross-section of a typical rotary furnace is shown in Fig. 2.

6.1.1 The furnace body is slowly rotated or oscillated during the melting thus bringing the underside of the metal bath into contact with the hot refractory lining. This action prevents lining from getting overheated by the flame and reduces the melting time to about half that of a stationary furnace.

6.1.2 Rotary furnaces range in capacity from 0.5 to 15 tonnes. They are largely used for the production of cast iron and can also be used for melting steels, copper, lead and aluminium alloys.

6.2 Refractory Considerations

6.2.1 Material

For various grades of cast iron melting, a monolithic lining, consisting of quartz with a suitable binder is used. This quartz is naturally occurring material and is crushed to various sizes to ensure maximum compaction with a maximum grain size around 6.50 mm. The maximum temperature which these linings can withstand is around 1 650°C approximately. Fireclay of sodium based bentonite is normally recommended as a binder.

Bentonite with a refractoriness of 1 150 to 1 350°C and very high shrinkage due to loss of water leads to a poorer campaign life. Fireclay with a refractoriness of 1 650 to 1 710°C and lower shrinkage due to loss of water leads to increased lining life.

6.2.2 The typical lining mix consists of the following:

a) Quartz material	80 percent by weight
grading:	
Size	Percentage by weight
6 - 5 mm	20
5 - 3 mm	40
3 - 2 mm	20
- 150 mesh powder	20
b) Binder	
Fireclay (30 percent Al_2O_3 Min)	20 percent
Moisture	8 - 10 percent
Green compression strength	0.86 - 1 kgf/cm ²

Quartz, along with binder has to be mixed in a suitable muller before taking up for ramming the lining.

6.2.3 Ramming

The mixed lining material is rammed by means of pneumatic rammers around metal formers to obtain the contour of the furnace lining. Care must be exercised to ensure that the lining is continuous and ramming is carried out to maximum compaction. The metal formers are withdrawn as the lining proceeds and can be used for subsequent relining of the furnace.

6.2.4 Sintering

The main shell and end cores are allowed to air dry for a week and subsequently lined through charcoal and fire wood. The furnace should be taken up for melting after the sintering is over and the melting

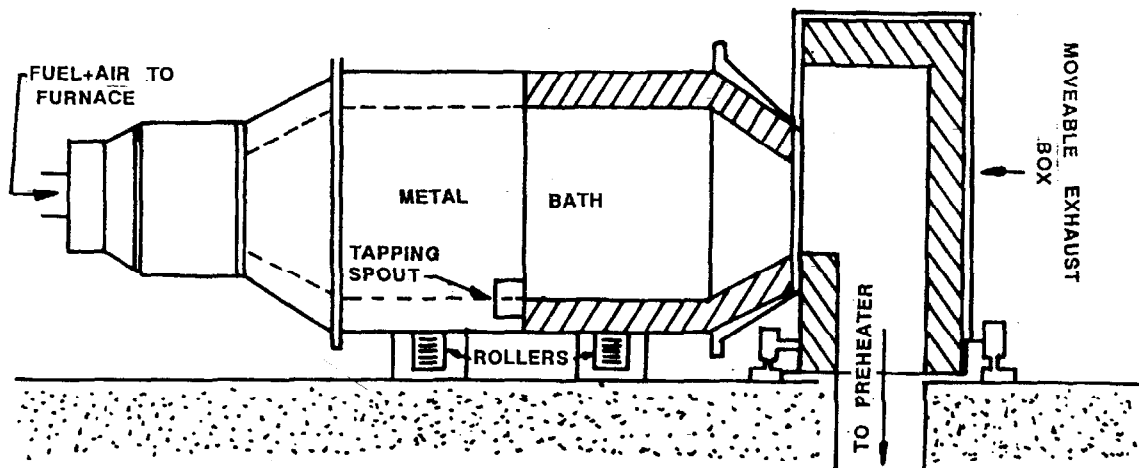


FIG. 2 ROTARY FURNACE

SECTION 3

should be carried out continuously to the extent possible under the prevailing working conditions of any set up so as to achieve overall efficiency of the furnace. The sintering cycle should be carried out in the following sequence:

- a) Air drying.
- b) Slow heating with charcoal and firewood.
- c) Assembling burner aide cone with shell.
- d) Mounting it on roller bed.
- e) Packing the gap at the joint face with ramming mass.
- f) Mounting the exhaust cone and packing the gap at the joint face with ramming mass.
- g) Formation of spouts.
- h) Heating up of the furnace (see Table 1).

7 ELECTRIC ARC FURNACE

7.1 Description

The electric arc furnace illustrated in Fig. 3 can be constructed for acid or basic steel making, melting of cast iron and copper alloys. The basic units of an electric arc furnace are carbon as graphite electrodes with an electrode control system, the melting chamber, furnace lining and tilting mechanism. The electrodes are clamped in electrode holders to which current is supplied. The electrodes move up and down on carriages. The electrodes are arranged at the apices of an equilateral triangle, where they pierce the roof. Water cooled collars or glands are so disposed as to cool the electrodes at this point and seal the opening, thus obviating an excessive chimney effect. The furnace lining which encloses the melting chamber, consists of the hearth, the roof and the side walls. The entire furnace is encased in a robust steel shell directly connected with furnace tilting mechanism which is used for tapping and slag removal. The roof lining is enclosed within a steel ring or frame work which can be detached from the furnace shell.

In electric arc furnaces, the heat required for melting and heating the metal is supplied by electric arcs at a temperature exceeding 3 000°C, the arcs being struck between the electrodes and the metal.

Table 1 Sintering Procedure

Heating Time (1)	Cooling Time (2)	Total Time (3)	Remarks (4)
15 min	5 min	20 min	
30 min	10 min	1 h	
1 h	15 min	2 h 15 min	
2 h	30 min	4 h 45 min	
3 h	30 min	8 h 15 min	
3 h	30 min	11 h 45 min	
3 h	30 min	15 h 15 min	
3 h	30 min	18 h 15 min	After this 25 kg of glass pieces are thrown into the furnace to glaze the lining surface.
3 h	30 min	22 h 15 min	
2 h	—	24 h 15 min	After this, charge the furnace immediately for melting.

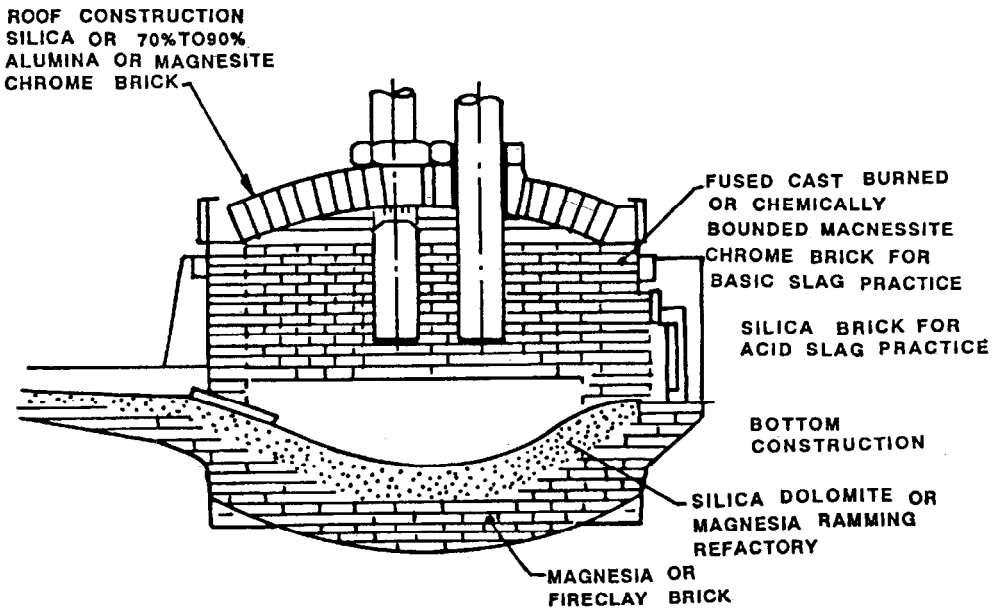


FIG. 3 TYPICAL ELECTRIC ARC FURNACE FOR STEEL PRODUCTION

7.2 Refractory Consideration for Lining of Electric Arc Furnace

7.2.1 Roof

7.2.1.1 Type of bricks

- Silica** — These are economical, but due to their low melting temperature and spalling propensity their campaign life is inferior.
- High alumina** — 70 to 80 percent alumina bricks, fired or phosphate bonded, are also used. These refractories have a higher melting point which allows a much higher temperature of operation. The campaign life is 2 to 3 times that of silica bricks.
- Fired magnesite chrome** — These bricks are economical to use only when the furnaces are hard driven.

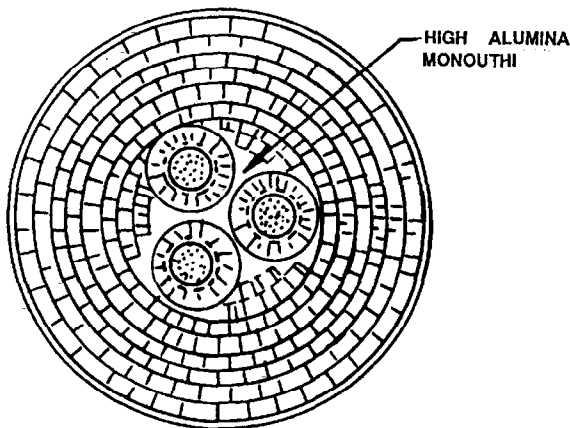


FIG. 4 ROOF CONSTRUCTION OF AN ELECTRIC ARC FURNACE

7.2.2 Physical and Chemical Property Requirements of Roof Linings

- Porosity** — The bricks should have a lower porosity to resist corrosive attacks of fumes and slags.
- Pore Size Distribution** — Bricks having fine pores are less vulnerable to low melting liquids formed at working face during operation.
- Thermal Expansion** — Slight expansion of the roof bricks on heating is always preferable, whereas a high shrinkage may prove disastrous.
- Refractoriness** — Higher the refractoriness the higher is the allowable operating temperature.
- Hot Modulus of Rupture, Torsional Creep and Elasticity** — These properties have great relevance to accommodate normal stresses developing at higher temperatures.

- Chemical composition** — The chemical composition has got to be compatible with the system so that the liquid phases appearing at higher operating temperatures are kept to a minimum.
- Accuracy of shapes** — This minimizes the cutting and dressing necessary during assembly giving a perfect contour which ultimately results in better stability and lower stress.

7.2.2.1 Typical properties of roof refractories are given in Table 2.

Table 2 Typical Properties of Roof Refractories

Characteristics	Requirements			
	Silica	High Alumina		
		70 % Al ₂ O ₃	80 % Al ₂ O ₃	
(1)	(2)	(3)	(4)	
SiO ₂ , percent	94 Min	—	—	
Al ₂ O ₃ , percent	1.5 Max	70 Min	80 ± 1.5	
Fe ₂ O ₃ , percent	—	3.5 Max	3.5 Max	
PCE (Orton), Min	31	36	36	
Apparent porosity, percent, Max	22*	24	25	
CCS, kg/cm ² , Min	300	225	250	
RUL, ta ° C, Min (2 kg/cm ²)	1 690	1 500	1 520	
P.L.C., percent, Max	+ 1.0 (1 450 ° C/2h)	+ 2.5 (1 500 ° C/1h)	+ 1.5 (1 600 ° C/1h)	

NOTE — Silica bricks conforming to IS 484 may also be used.

*Bricks with lower apparent porosity are preferred.

7.2.3 Lining Procedure

The arc furnace roof has been mostly standardized to dome shaped sprung arch of varying thickness from 150 to 300 mm depending upon the size and capacity the prepared thickness being 230 to 300 mm. The dome shaped bricks are supported either directly by the water cooled metallic roof ring or by special shaped *akew* back bricks resting on the water cooled ring. The roof bricks are held in position by providing a certain amount of rise which varies 80 to 100 mm per metre span for silica to 150 mm for basic bricks.

7.2.3.1 Larger bricks used in roof construction are more prone to spalling than the smaller bricks. The smaller bricks have also an added advantage for the manufacturer to produce them easily with greater accuracy and better properties. They also provide a better scope for distribution allowances during construction which minimizes the stress during the initial heating.

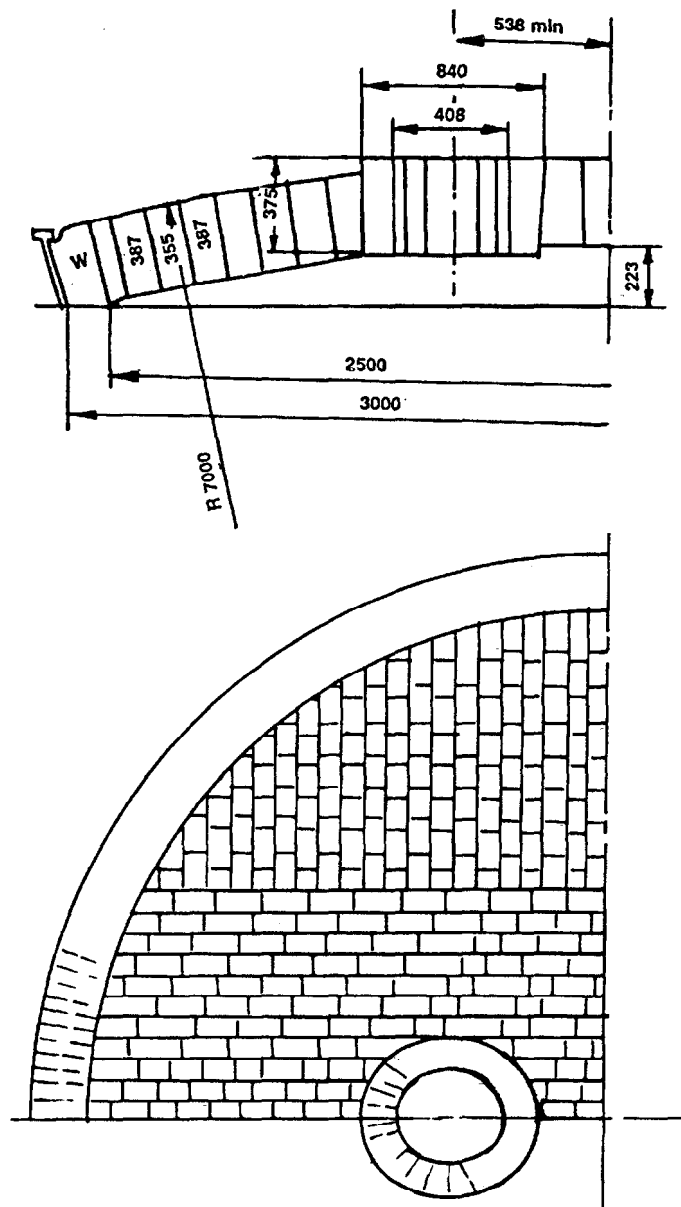


FIG. 5 BRIDGE TYPE ROOF OF AN ELECTRIC ARC FURNACE

7.2.3.2 The roof construction is broadly divided into two types:

- a) Annular ring type.
- b) Bridge type.

These types have also been further rationalized with simpler standard dome shapes for different sizes of roofs and the unwidely shapes near the delta portion have been avoided by use of good quality ramming masses or plastics. Some typical roof construction details are shown Fig. 3, 4 and 5.

7.3 Side Wall

7.3.1 Basic Slag Practice

The side walls of an arc furnace are built with basic key bricks with a back up lining of fireclay bricks.

The pouring spout is made with aids arch bricks, and the slag door can be constructed with the same size key bricks or with special door jamb blocks near the pillars for bigger furnaces (with mechanical feeding arrangement). It is customary to use ordinary fire bricks as safety lining and burnt magnesite bricks as the working lining upto the sill level. For high power furnaces, where conditions are extremely severe, fused cast magnesite chrome bricks are used in slag lines and hot spots for better life. Dense Magnesite bricks and magnesia carbon bricks are also used for improved life of at the slag level also give improved life of at the slag level. Above sill level normally magnesite chrome chemically bonded steel bricks are used.

7.3.2 Acid Slag Practice

These are built of super duty silica brick, often dry with the normal 1 to 100 mm expansion allowance. The door arches and jambs are built of silica, or high alumina refractories to minimize spalling.

7.3.3 Physical and Chemical Property Requirements

- Porosity** — The bricks must have low porosity to resist penetration of slag and corrosion.
- Bulk density** — Since a dense brick is resistant to slag and metal penetration a high bulk density is preferred.
- Refractoriness** — Since extremely high temperature prevails in this zone due to arcing, bricks with high refractoriness give better life.
- Cold crushing strength** — Since the mechanical abrasion is severe on the wall during scrap charging, a strong brick having high cold crushing strength is suitable for resisting the erosion.
- Spalling** — Bricks prone to spalling may peel off during temperature fluctuations and for this reason bricks used in the side walls (specially above the sill level) should be spall resistant in nature.
- Chemical composition** — The chemical compatibility of the brick with the process pays a vital role. The liquid phases appearing at high temperatures and due to interaction of the process material with the bricks have to be carefully studied, for example a burnt magnesite brick is compatible with a slag having high FeO and CaO content.

7.3.3.1 Typical properties of side wall refractories are given in Table 3.

Table 3 Typical Properties of Wall Refractories

Characteristics	Requirements		
	Chrome Magnesite (Refer IS 3305)	Magnesite Chrome (Refer IS 3304)	Dense Magnesite
(1)	(2)	(3)	(4)
MgO, percent, <i>Min</i>	30	55	85
Cr ₂ O ₃ , percent, <i>Min</i>	18	6	—
Apparent porosity percent, <i>Max</i>	24	24	17
CCS, kg/cm ² , <i>Min</i>	250	250	600
RUL, ta°C, <i>Min</i> (2 kg/cm ²)	1 600	1 550	1 550
P.L.C., percent, <i>Max</i> (1 600°C/2h)	+ 1.5	+ 1.0	+ 1.0

7.4. Bank and Bottom

7.4.1 Basic Slag Practice

In basic electric arc furnace, the lower side walls near the bank and bottom are lined with 2 to 3 courses of burnt magnesite bricks over the fire bricks safety layer. The magnesite bricks should have high ccs, low porosity and high bulk density. The mode of bottom construction may vary depending on the shape of the shell which may be either spherical or with a flat base tapering up gradually. The construction is generally of stadium type, having steps at different levels. Over these steps, a monolithic basic hearth is rammed pneumatically to give an inverted dome shaped bottom with sloping banks to hold the liquid metal. The final sintering of the monolith is achieved during the initial heating and melting operation. The shapes of the bank and bottom is maintained by regular fettling and patching.

7.4.2 Acid Slag Practice

The subhearth consists of silica bricks laid dry with an expansion allowance of 1 mm per 100 mm over 1 or 2 courses of fireclay bricks. The monolithic bottom is made with a mixture of ganister (size 10 mm downwards) plus 10 to 20 percent plastic fireclay and minimum possible water consistent with good ramming quality. The mixture is either sintered into place in layers by means of the arc or completely rammed pneumatically, each layer being roughened before the next is applied.

7.4.3 Typical properties of monolithic refractories for arc furnace bottom are given in Table 4.

Table 4 Typical Properties of Monolithic Refractories for Arc Furnace Bottom

Characteristics	Requirements
(1)	(2)
Type	Magnesite
MgO, percent	84 <i>Min</i>
Setting	Chemically or heat setting
Grading, mm	0 - 5
Service temperature, °C	1 800 <i>Max</i>

SECTION 4

7 CORELESS INDUCTION FURNACE

7.1 Principle of Operation

The coreless induction furnace operate on the principle that metal could be melted by its resistance

to the passage of electric current induced within it. The furnace is basically an aircore transformer in which the furnace coil is the primary and the charge to be melted is the secondary. The biggest advantages are its simplicity of construction and easy operation. The coreless crucible, type furnace can also be operated at mains, medium or high frequencies. These are mostly used to melt cast iron and alloys both ferrous and nonferrous of various compositions.

7.2 Construction

These types of furnaces constitute essentially a water cooled coil through which high frequency alternating current is passed and a refractory crucible inside which the charge is melted. Typical construction is given in Fig. 6.

7.3 Lining Technique

7.3.1 Dry Monolithic Lining with Steel Liner Method

- a) The water cooled copper coil of the furnace is coated with a suitable refractory mass (70% silica + 30% calcium aluminate). This is a safety measure taken to protect the coil from molten metal in case of a break through.
- b) Dry ramming mass is thoroughly mixed with requisite quantity of sintering agent such as boric acid). The prepared mass is then thoroughly dried over a light fire in a clean metallic pan for removing the moisture before use.
- c) Then the furnace coil is insulated with any more of the three insulating materials described in Table 5, and the bottom of the coil is bricked to provide a tight seal.
- d) Compacting the ramming mass (Typical characteristics are given in Table 6).

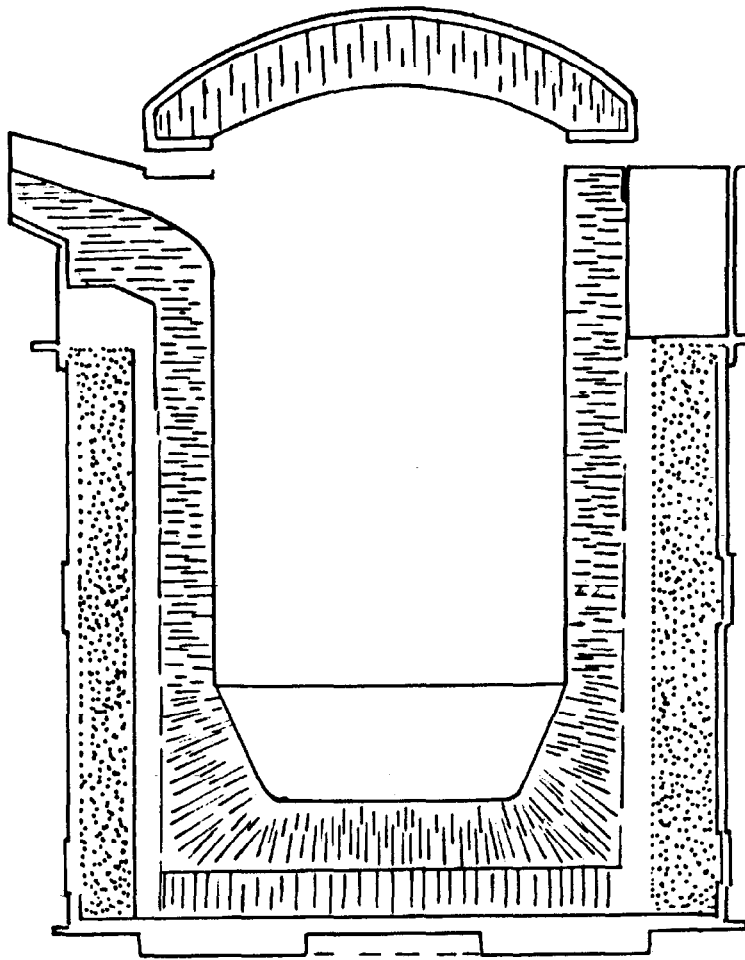


FIG. 6 CORELESS INDUCTION FURNACE

Table 5 Insulating Materials for Coreless Induction Furnaces
[Clause 7.3.1 (c)]

Characteristics	Requirements		
	Asbestos (2)	Ceramic Fibre (3)	Moist Felt (4)
Raw material base	Asbestos	Alumina Silicate Fibre	Alumina Silicate
Type of bond	Organic	-	Silicate gel
Service temperature, °C <i>Max</i>	500	1 260	1 260
Asbestos, percent, <i>Min</i>	97	-	-
Al ₂ O ₃ , percent	-	45	34
Si O ₂ , percent	-	54	65
Bulk density kg/cm ³	1.0 - 1.1	0.05 - 0.2	0.24 <i>Min</i>
Thermal conductivity W/m °K	0.17 - 0.29	0.08 - 0.22	0.06 - 0.17
Supply form	Plates, board 2 - 10 mm thick	Plates, board, Blanket 2 - 25 mm thick	Moist blanket 3 - 25 mm thick

NOTES

- Excessive insulating effect is dangerous since it results in heavy sintering and fettering of the dry monolithic lining and thus in susceptibility to cracking.
- The surface of the insulating material should be as solid and smooth as possible, to enable the ceramic crucible to expand or shrink freely in accordance with the change of temperature.

7.3.2 Manual Method

- The bottom of the crucible is rammed alternately with flat headed and spiked tool, upto a level slightly higher than the specified height. The extra rammed material is then scrapped out from the top and the level is checked by a spirit level. Then the mild steel former (in case of reusable former, it is given a very thin oil/graphite/petroleum coat), is placed at the centre and hold in position by wooden wedges. To prevent the former from getting displaced during ramming a heavy weight is placed inside the former. The annular space between the asbestos sheets and steel former is rammed alternately with spiked and flat head rammers from the top. Depending on the size of the furnace, 2 to 4 persons are engaged for hand ramming, the persons are made to rotate continuously till the lining is completed.
- For the top 75 to 100 mm. Where there is no coil dilute sodium silicate is added with the ramming mass for developing strength initially after air drying. For the pouring out spout, the mass is also prepared with dilute sodium silicate solution.
- Compaction by electric vibrations is becoming popular. This is a labour and time saving process, also dust generation is much reduced. Depending on the furnace size the following vibrator are recommended.

- Twin arm vibrator for furnace size 1 to 8 tonnes.
- Three arm vibrator for furnace size 6 to 40 tonnes.
- Four arm vibrator for furnace size 30 to 70 tonnes.

NOTE — Formers used either may be consumable or reusable type. Reusable Former, one place slightly conical former and core angle 1 to 1.5°, may be reused by this process.

Table 6 Chemical Composition and Physical Properties of Monolithic Refractories for Coreless Induction Furnace
[Clause 7.3.1 (d)]

Characteristics	Requirements		
	Acidic Silica (2)	Basic	
		Magnesite (3)	Magnesite Chrome (4)
(1)			
Si O ₂ , percent	97.5 <i>Min</i>		
Al ₂ O ₃ , percent	0.8 <i>Max</i>		
Fe ₂ O ₃ , percent	0.6 <i>Max</i>		
MgO, percent	-	75 - 85	68 - 75
Cr ₂ O ₃ , percent	-		7 - 10
Refractoriness (Orton)	32.5 - 33	38 <i>Min</i>	-
Bulk density kg/cm ³ (rammed or vibrated)	2.1 - 2.2	2.6 - 2.65	-
Moisture content, Percent (without sintering agent)	0.05 - 0.2		
PLC at 1 400 °C/2h, <i>Max</i>	+ 4 percent	-	-
Setting	Chemical	Chemical	Chemical
Service Temp °C	1 650 <i>Max</i>	1 650 <i>Max</i>	1 750 - 1 800
Typical grain size			
1 - 5 mm	30 percent	0 - 3	
0.06 - 1 mm	50 percent		
0 - 0.06 mm	20 percent		

NOTES

- Basic linings are used in coreless induction furnaces when a basic reaction with the slag and metal is desired. It can also be prescribed for melting alloy steels.
- Silica linings are extensively used for melting of cast iron. It can also be used for melting plain carbon and low alloy steels.
- For melting of non-ferrous alloys (copper, aluminium and zinc alloys), where operation temperature is low lining with wet ramming mass is done. The ramming mass is mixed with water and additives, and rammed manually or by pneumatic rammers. The former used consists of 3 or 4 detachable pieces which can be easily removed after ramming.

7.3.3 Sintering

The lining is finally consolidated to a monolithic structure by this process.

- Conventional sintering with (lost) melt out formers and consists of the following steps :
 - Inductive heating of former with or without starting blocks, alternatively

thereto, burner heating. Rate of heating 50 to 150°C/h depending on furnace size.

- When the starting blocks or the former begin to melt, addition of clean scrap or liquid charge.
 - Raising the filled, liquid crucible to sintering temperature, 50°C above working temperature but minimally 1 500°C.
 - Holding at sintering temperature from one to several hours.
- b) A-bridged method with (reclaimable) permanent former and consists of the following steps:
- Preheating former to 450°C in 1 to 2 h which may be done inductively, with burners, or a combination thereof.
 - Holding at 450°C in 30 to 60 minutes, depending on furnace size.
 - Rapid cooling of former by compressed air in 15 to 20 minutes.
 - Removal of former.
 - Followed by further fast heating with the burner, by 200°C/h, or placing of starting blocks and inductive heating, then melting and endeavoring to hold at the desired sintering temperature.

7.4 Lining Repair

The monolithic lining can be repaired either after cooling the furnace or in hot condition. After

emptying and cooling the furnace the adhering slag or metal at the worn out or cracked zones are chipped off. In case of deep cracks V grooves are made. Then plastic patching mass (consisting of fine fraction of the same ramming mass plus sodium silicate) is filled into the effected area and a wash of the same material applied. For repairs in the hot condition dry spray guns or slurry guns are used.

7.5 Roof

Usually roof refractories are cast of 50 to 70 percent aluminol materials or rammed with 60 to 90 percent alumina heat setting plastic ram materials.

SECTION 5

8 LADLES

8.1 Lip Pouring and Teaspoon Ladles

Following types of refractories are recommended:

- a) High duty fire brick,
- b) 50 to 55 percent alumina bricks,
- c) Silica clay ramming mixes, and
- d) Plastic refractories containing graphite.

8.2 Bottom Pouring Ladles

Following types of refractories are recommended:

- | | | |
|---------------------|---|--|
| Shell lining | — | Fireclay bricks (<i>see</i> IS 6) |
| Stopper rod sleeves | — | Quality fireclay (<i>see</i> IS 6) |
| Stopper | — | Clay graphite |
| Nozzle | — | 50 – 55 percent Al ₂ O ₃ |

(Continued from second cover)

- p) Refractories for the glass fibre industry; and
- q) Refractories for the iron and steel industry.

Each recommendation will cover the following aspects of the refractory engineering:

- a) Process of manufacture used;
- b) Types of boilers/furnaces systems;
- c) Objectives of the refractory lining;
- d) Design engineering features of the furnaces;
- e) Principal zones and sections of the furnaces;
- f) Service conditions in different zones including service temperatures;
- g) Details of lining used in various zones and sections;
- h) Refractory installation practices used for the boilers/furnaces;
- j) Consumption pattern of refractories;
- k) Application standards, namely Indian and other standards, design codes, stress, considerations, etc; and
- m) Miscellaneous aspects not covered from (a) to (k).

This standard covers the recommendations for refractories use in foundry industry and has five sections covering cupolas, rotary furnaces, electric arc furnaces, coreless induction furnaces and ladles used in the foundries. It is endeavored to cover the principle of operation of the furnace type, constructional details, types of linings, typical properties of linings, recommended refractory materials and the methods used in the lining of furnaces.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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